The influence of consumption of Ultra-Processed foods on obesity among Uruguayan and Brazilian preschoolers

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Introduction

There is growing consensus globally that the consumption of ultra-processed food (UPF) can negatively affect the nutritional status of children, with far-reaching consequences into adulthood (1). An emerging line of inquiry explores the role of food processing, some associated risks later in life include obesity, cardiovascular and cerebrovascular disease, type 2 diabetes, depression, different types of cancer, and premature death (2).

Ultra-processed food is categorized by the NOVA classification system defined by the Global Health Research Program to be “formulations of ingredients, most of exclusive industrial use, typically created by series of industrial techniques and processes” (3), and some examples of these include: carbonated soft drinks; sweet, fatty or salty packaged snacks; candies; packaged bread and buns, biscuits, pastries, cakes; margarine; sweetened breakfast, packaged cereals, fruit yogurt and energy drinks; pre-prepared meat, cheese, pasta and pizza dishes; poultry and fish ‘nuggets’ and ‘sticks’; sausages, burgers, hot dogs and other reconstituted meat products; powdered and packaged ‘instant’ soups, noodles and desserts; and infant formula.

The convenience of UPFs due to their low cost, highly palatable, addictive taste, ease of accessibility, ready-to-consume with minimal preparation, and persuasively marketed, which may promote overconsumption, led to these foods being consumed more than any other type of food, despite public health campaigns encouraging people to avoid over-consumption of these products (4,5). Several unique non-nutritional features of UPF have been proposed as potential mechanistic links through which these products may promote obesity independent from their nutrient content. The basic ingredients, physical and structural characteristics and processing techniques of these products are used to induce passive overconsumption (6). UPF, may alter eating patterns, promoting shifts toward snacking and eating while engaged in other activities (e.g., eating while watching television). These eating behaviors promote rapid eating rate and inattentive eating that can interrupt digestive and neural mechanisms that signal satiation and satiety, possibly leading to overconsumption (7). Several studies have examined the evidence for specific types of UPF, for example finding higher consumption of sugar-sweetened beverages, fast food, potato chips, fried potatoes, or sweets is associated with a higher risk of weight gain or obesity. However, in terms of research, classification of foods and beverages by degree of food processing can potentially provide novel insight into dietary factors that contribute to obesity risk by identifying an entire class of foods with poor nutritional quality, rather than focusing on individual nutrients or specific food items (8).

The Pan-American Health Organization has determined that over recent years sales of ultra-processed products have risen rapidly, including in Brazil and Uruguay (1). According to data from the Brazilian National Health Survey, 31.3% of students consume, five or more days of the week, snacks, soft drinks, and salty UPF, respectively (9). It has also been determined in Brazil that the price of ultra-processed foods has been inversely associated with the prevalence of being overweight and obese, with a higher prevalence in low-socioeconomic populations (6). This is particularly concerning, as UPFs are cheap, conveniently packaged and therefore with Brazilian children now consuming them on a grand scale, if not promptly addressed could lead to significant health problems in this population in the future. In Uruguay, the sales of UPFs have shown the fastest growth rate in Latin America: 68.4% between 2000 and 2013 and the perception of the healthfulness of these products have differences across income levels, low-income people's have difficulties to recognize their potential negative effects on health. A recent publication showed that Uruguayan schoolchildren are consuming calories in excess and that UPFs comprised 28% of their daily intake on average (10).

Although many studies highlight the importance of UPF consumption in school-age children, there is less available information focusing on younger children, and there is even less available research in these two countries investigating associations with the demographic, socioeconomic, and nutritional status of children. Of the 10 studies of UPF and obesity examined in the narrative review of Poti et al. only 6 included pediatric populations, and 2 of them were focused on preschoolers (8). Last year was published the first study analyzing the relationship between UPF consumption and dietary nutrient profiles linked to obesity in children and adolescents using nationally representative data from different countries in diverse regions. This multicountry study included preschooler children of Argentina, Australia, Brazil, Chile, Colombia, Mexico, the United Kingdom, and the United States (11).

There is a critical need for further studies designs to explore the role of UPF in the early stages of life, in different populations, locations, and contexts and in population-based samples with greater generalizability. Therefore, identifying these associations is essential in order to guide public policy and educational actions regarding health and nutrition. The present study aims to evaluate potential associations between the consumption of UPF and the nutritional status in a sample of Uruguayan and Brazilian preschoolers belonging to two cohort studies: The ENDIS Study and the Pelotas 2015 Birth Cohort

Methods

We conducted a cross-sectional analysis using data from preschool children from population-based surveys in two Latin American countries, Uruguay and Brazil. Uruguay is a country located in the southern part of the South American continent. It is a country with an extension of 176,215 square kilometers (Km^2) and a population of approximately 3.5 million inhabitants, with an HDI of 0.765 (12). Brazil is a continental country (approximately 8.5 million km^2) also located in South America. We used data from the city of Pelotas, in the state of Rio Grande do Sul. Pelotas is a city with nearly 350,000 inhabitants located in the south of Brazil with an HDI of 0.739 (13).

The sample size and power for our study were calculated considering the primary outcome as the prevalence of obesity. Our estimated sample size was informed by the results of Corvalan et al. who described a prevalence of overweight and obesity in Brazil and Uruguay of 7.3% and 7.2% respectively in children under 5 years (14). Assuming that the intake of UFP (as a continuous variable) will increase the prevalence of obesity in children and the effect size of odds ratio (OR) would be similar to the study of da Costa et al. (OR: 2.74 in 5^{th} quintile of intake in comparison with 1^{st} quintile in children of 10 years onwards) (15), with 90 % power assuming a two-sided test at alpha = 0.05, the final sample size would be of at least of 242 young children with obesity and the same amount without obesity.

The first included survey is the *"Encuesta de Nutrición, Desarrollo Infantil y Salud"* (ENDIS) (Health, child development and nutritional survey), a comprehensive, longitudinal study conducted by the Uruguayan Ministry of Social Development. For the first cohort (2013-14), a representative sample selection of children born in Uruguay between 2009-2014 at the country level was conducted based on the *"Encuesta Continua de Hogares" (*ECH) (Continuous Household Survey, in urban locations with more than 5,000 inhabitants (16). Children aged 0 to

3 years and 11 months of age were eligible for the study. In 2013-14, 3,077 children were assessed (1^{st} wave), of which 2,383 were followed-up in 2015-2016 (2^{nd} wave) (17). Similar methodology was applied to the 2018 ENDIS cohort (18). For the present study, we used data from children with available information on nutritional status and UPF consumption from the 2013-14 1^{st} (n=939), 2^{nd} (n=2052) and the 2018 (n=1851) ENDIS surveys. For those who were assessed during both the 1^{st} and 2^{nd} waves from the 2013-14 surveys, only data from the 2^{nd} wave was included.

The second study is the Pelotas 2015 Birth Cohort (Brazil). In the year 2015, all live births between January 1 and December 31, for mothers that lived within the urban area of Pelotas were included in the survey. A total of 4,387 live births that occurred in Pelotas in 2015 were eligible to be included in the Cohort and 4,275 were included in the study. Children were then followed at 3, 12, 24 and 48 months. For the present study we used data from the 48 months Pelotas cohort follow-up (19).

Nutritional Status

Anthropometric measurements were performed at each site by trained field workers. Children's weight, recumbent length (children up 2 years old) and height (children over 2 years old) were collected. In the Uruguayan cohorts, data was collected using a Seca scale (sensitivity of 0.1 kg) and stadiometer (sensitivity of 0.5 cm). In Brazil, a TANITA® scale (model UM-080, sensitivity of 0.1 kg) and Harpenden® stadiometer (sensitivity of 0.1 cm) were used. Children were measured wearing light clothes and without shoes. BMI was calculated as weight (in kg) divided by length or height (in m^2). Obesity was defined as BMI for age and sex ≥ +3 z-scores or weight for length of height and sex ≥ +3 z-scores, according to the WHO standards (20). All anthropometric data were processed using Anthro Plus software from World Health Organization (version 1.0.4; World Health Organization; Geneva, Switzerland).

UPF consumption

For dietary intake information, respondents answered diet questionnaires that included lists of food and drinks consumed by the child. For the 2013-14 1^{st} wave ENDIS and the 2018 ENDIS cohorts' 24-hour recall periods were used, for ENDIS 2^{nd} wave cohort the reference period was the previous week. For the 2013-14 1^{st} wave ENDIS participants were asked about the child's intake using the following question: "Thinking about yesterday, <child's name> did he/she eat/drink ...?". The options were the following food items or subgroups: soup, pure, stock cubes, fried potatoes; soft drink; chocolate milk; nuggets, hamburger or sausages; packaged salty snacks; candies, lollipops, chewing gum, chocolate, or jelly; sandwich cookie or sweet biscuit; juice in can or box or prepared from a powdered mix; yogurt. For the 2013-14 2^{nd} wave ENDIS participants were asked about the child's intake of the same food items, except that chocolate milk was not asked, and the question was: "Thinking about last week, <child's name> did he/she eat/drink ...?", and then they asked about weekly frequency. For the 2018 ENDIS cohort participants were asked about the food items child's intake "yesterday" and the same food items of 2013-14 2^{nd} wave ENDIS. For the Pelotas 2015 cohort participants were asked about the child's intake using the following question: "Thinking about the <child's name> usual consumption, does he/she eat/drink ...?". The options were the following food items: soup, pure, stock cubes, fried potatoes, instant noodles; soft drink; chocolate milk; nuggets, hamburger, sausages; packaged salty snacks; candies, lollipops, chewing gum, chocolate, or jelly; sandwich cookie or sweet biscuit; juice in can or box or prepared from a powdered mix; yogurt.

Data on dietary intake were obtained by trained interviewers using standardized questionnaires at all cohorts. The items were grouped according to the NOVA classification, based on the extent and purpose of industrial processing. According to the objectives of this study we excluded non-UPF food items. Food considered as UPF was processed meat products (hamburgers, hot dogs, and poultry and fish nuggets), ready to heat and/or eat food (soup, pure, stock cubes, fried potatoes, instant noodles), packaged dairy desserts, sweets (i.e. candy, chocolate, jelly, ice cream), cookies (i.e. biscuits, cakes), chips, chocolate milk, and sweetened drinks (i.e. soft drinks or artificial juices). Each positive answer was added up to create a UPF score ranging from zero to six or more UPF (0; 1; 2; 3; 4; 5; 6 or more). The largest category also included 7 and 8 UPF, since the samples in this category were mostly at a frequency of 6. The score of UPF consumption was the main exposure measured.

Covariables

A set of covariables was used to describe UPF consumption in our sample: country, child's sex (male/ female), age in months, family income (terciles), and exclusive breastfeeding duration (quintiles and terciles). All characteristics were answered by mothers or child´s responsible.

Analysis

Descriptive analysis of participants from the total sample and from each cohort according to included covariables, consumption of each UPF group and the UPF scores were carried out. Furthermore, the sample was described considering the nutritional status.

At first, we considered a multilevel analysis, intending to nest the individuals within groups (cohorts or countries). The Intraclass Correlation (ICC) was calculated to assess the amount of variance due to clustering. The ICC was low, so we had a small relative proportion of cluster variance to the total variance. Therefore, we used the fixed effects approach that allows us to compare the clusters to each other.

Crude and adjusted logistic regressions were performed to estimate odds ratios, and respective 95% Confidence Intervals (95%CI), for the associations of UPF consumption and nutritional status in preschoolers. In addition, the distribution of the data of obesity over the UPF score as a continuous interval, using a Kernel smoothing was plotted.

Statistical significance was set at $p<0.05$. Statistical analyses were performed in Stata version 14.1 and R version 4.1.1.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Ethics Committee of the School of Medicine from the University of the Republic of Uruguay (Resolution no. 159 of the session from March 18, 2013 from the School of Medicine, file number 070153- 000486-13) and by the School of Physical Education (ESEF) Ethics Committee, associated with the *"Comissão Nacional de Ética em Pesquisa"* (CONEP) (National Research Ethics Committee) (approval number 26746414.5.0000.5313)for Brazilian participants. Written informed consent was obtained from all subjects

Results

The final sample consisted of 8,687 preschool children, 50.8% belonging to the Uruguayan 2013, 2015 and 2018 cohorts, while the remaining 49.2% belonged to the 2015 Brazilian cohort.

The children´s and household socioeconomic characteristics and descriptive information on the children´s anthropometric and nutritional status for every cohort are presented in Table 1. Children's mean age was about 43.4 (SD ± 7.31) months and there was a similar proportion of female and male children within the sample. About 55% of mothers had between 6 to 12 years of education.

The obesity prevalence estimated by weight for length/ height Z-score was 4.59% ranging from 2.53% in the Uruguayan 2013 1st wave cohort to 5.40% in the Brazilian cohort. The overall prevalence of childhood obesity estimated by BMI for age Z-score was 4.61% ranging from 2.41% in the Uruguayan 2013 1st wave cohort to 5.43% in the Brazilian cohort. Mean breastfeeding duration was 3.38 (SD ± 2.46) months (Table 1).

Table 2 shows the mean score of UPF consumption, in the studied sample, the mean intake was 3.52 (SD ± 2.53). As shown in Table 2, individuals from different cohorts presented a significant difference in intake of UPF. In Brazil, this mean reached almost 5 UPF while in Uruguay, among 1 to almost 3 (2.53 and 1.23 for the 2013 Cohorts, 1st and 2nd wave, respectively and 2.13 for the 2018 Cohort).

With respect to the eight groups of UPF analyzed, the UPFs groups that were more frequently consumed were bottled or packaged dairy desserts, filled cookies or biscuits, sweets (i.e. candy, chocolate, jelly, ice cream) and refreshments. In terms of frequency, more than 50% of children usually ate packaged dairy desserts (63.43%), cookies (62.90%), and sweets (55.65%), over 46% drink sweetened drinks, almost 43% usually eat processed meat products, and around 30% usually eat snacks (34.90%), chocolate milk (34.84%) and ready-to-eat meals (29.47%). The cohort with the higher proportions of UPF consumption for individual groups was the Brazilian study, where 90.01% of the included children consumed packaged dairy desserts, 89.39% frequently ate cookies or cakes, and 76.28% sweets. In Uruguay, the study with the higher proportions was the 1st wave of the 2013 cohort with 51.07%, 48.82%, and 59.10% for packaged dairy desserts, cookies and sweets, respectively (Table 2).

To evaluate the prevalence of obesity in the cohort on the basis of the BMI for age and sex ≥ +3 z-scores according to the WHO standards, we examined the proportion of subjects with obesity, between socio-demographic characteristics, exclusive breastfeeding duration and UPF intake groups and score of UPF consumption (Table 3). Results showed that obesity was higher among older children (mean age of children with obesity 44.88 months and 43.35 months in children without obesity, p: <0.001) and those with higher weight z-scores at birth (8.25% in children with z-score higher than 1, p: 0.000). Longer breastfeeding duration was associated with lower prevalence of obesity in the studied children (3.38% in the 4th quintile and 3.59% in the last quintile, p: <0.001).

Among the individual UPF groups included in the analysis, the consumption of packaged or ready to heat and/or eat meals determined a prevalence of obesity of 5.43% in the group of regular consumers compared to 4.23% for those who do not (p: 0.029). The intake of chocolate milk was associated with higher prevalence of obesity in early childhood, 5.73% in the group that consumes this on a regular basis compared with infrequent consumers (3.63%, p: 0.001). We found no relationship between the number of UPFs eaten by children with obesity, however children without obesity consume less UPF than children with obesity (3.4 and 3.9 respectively) (Table 3).

Table 4 presents the multivariable associations between obesity and the score of UPF consumption. We didn’t observe a relationship between the score of UPF consumption and obesity, the odds ratio (OR) was 1.04 (95% CI, 1.00–1.09). Adjustments resulted in modest attenuation of the relationship and lack of statistical significance. Since the associations were quite similar by sex, the final analysis combined both sexes. No association between the score of UPF consumption and obesity was observed in each cohort separately. We decided to analyze data separately for groups of age, considering differences in the descriptive analysis by age. The score of UPF consumption was directly associated with childhood obesity in children under 48 months. The likelihood of obesity increased by 10% per each point of the score of UPF consumption. Adjustments for infant sex, birth weight, family income and cohort showed similar association. However, additional adjustment for duration of exclusive breastfeeding resulted in lack of association of obesity with score of UPF consumption. There were no associations between UPF score and obesity in older children.

The Figure shows the distribution of obesity data over the UPF score as a continuous interval, using a Kernel smoothing to plot values, allowing for smoother distributions by smoothing out the noise. The density plot displays the association based on the analysis by age groups. The peaks of the density plot help display where values are concentrated over the interval. In the case of the population under 48 months, the peaks of obesity are concentrated at the score of 6 or more UPFs.

Discussion

This study of data of young children, with a mean age of 43 months, shows that for every 100 children assessed in these four cohorts, four were obese. In previous decades, the prevalence of obesity in children increased worldwide, which presents a major public health concern. In developing countries, the transition from rural agrarian to urban economies has accelerated the obesity increase (21). Excessive fat in childhood is a risk factor for later adult disease and is associated with impaired health during childhood itself, including chronic low-grade inflammation, increased risk of hypertension, insulin resistance, fatty liver disease, orthopedic dysfunction and psychosocial distress (22). Once established, obesity in children (as in adults) is hard to reverse. There have been widespread calls for regular monitoring of changes in overweight and obesity prevalence and their risk factors, in order to plan services for the provision of care and to assess the impact of policy initiatives (20,23).

Obesity was slightly more frequent in boys than in girls, and all estimates were heterogeneous. The prevalence increased with birth weight and age and decreased with breastfeeding. In a review of the literature, most studies showed a positive correlation between birth weight and childhood obesity (24,25). The highest obesity prevalence was observed in children of the first quintile of breastfeeding duration. However, it is important to highlight that even with differences among the upper quintiles of breastfeeding duration, the prevalence of obesity was always high (3.38 to 3.98%). In both countries, income growth has resulted in better access to food for the overall population, however, Brazil shows more inequities (26). Since then, there have also been increases in negative lifestyle changes, such as sedentarism and excessive intake of high-calorie foods, which could explain the progressive increase in obesity and chronic diseases (2,27–29). The latter indicates that the current situation is characterized by a rapid change toward a post-transition stage.

Associations of obesity with cohort and country were also detected. The highest obesity prevalence was observed in Brazilian children. In Brazil, a meta-analysis of studies conducted between 1986 and 2015 found high prevalence rates of obesity in the South regions of the country (10.6% [10.2−11.0%]) (30). Meanwhile, a study on Uruguayan preschoolers found that 9.6% of toddlers under 2 years and 11.6% between 2 and 4 years had been overweight or were obese (28). Nevertheless, the national data of adult population shows similar prevalence of overweight and obesity. In the case of Brazil, the ELSA-Brasil study found a mean BMI in the adult population with a range of 26.07 to 27.92 with differences by sex and race (31). In 2018, the prevalence rates of excess weight (BMI $\geq$ 25 kg/m^2) and obesity (BMI $\geq$ 30 kg/m^2) in Brazil were as high as 55.7% and 19.8%, respectively (29). Meanwhile in Uruguay the prevalence of excess weight in population between 15 to 64 years was 58.5% and the prevalence of obesity was 23.7% (32). However, analyzing the Global Burden Disease estimated attributable mortality, years of life lost, years of life lived with disability and disability-adjusted life-years, obesity is more relevant risk factor for Brazilian population of the Rio Grande do Sul State in relation to Uruguayan population (33,34).

This study shows that higher consumption of UPF is associated with obesity in Uruguayan and Brazilian children younger than 4 years, each serving increase in the intake of UPF resulted in an increase of 10 percentage points in obesity prevalence. These results were materially affected by additional adjustment for the duration of exclusive breastfeeding, which suggests that exclusive breastfeeding alters the associations may partly control for a competing mechanism, i.e. exclusive breastfeeding is associated with adequate complementary feeding later. Another possible explanation was an overadjustment by the influence of family income in the duration of exclusive breastfeeding as we found in our prior study with the ENDIS Cohort 2013 1st and 2nd wave (35).

Our results agreed with previous studies suggesting that greater UPF consumption predicts large gains in overall and central adiposity and may contribute to the inexorable rise in obesity (36,37). The potential for UPF to affect weight depends on whether consumption of calories from these products is above an individual’s usual caloric intake (and is not offset by a compensatory decrease in intake of calories from other sources or by an increase in energy expenditure). The positive gradient between obesity and UPF is consistent with the high energy density of these products (38,39). In the case of Brazil, the typical diet is high in sugar, probably the result of Brazil being for centuries the world’s largest producer of sugar, and of table sugar being the cheapest source of calories in the country (40). However, some authors have pointed out UPF consumption as an obesity vector, not only due to its energy density, but also because of several other factors not related to the diet's nutrient profile. In animal models, high doses of monosodium glutamate (a usual food additive used in ultra-processed manufacturing) are toxic to neurons involved in the regulation of metabolic homeostasis, including secretion and action of insulin, leading to an increase in fasting blood glucose levels and severe visceral fat accumulation (41). Additionally, UPF would provide readily accessible and more easily digestible substrates that can facilitate growth potential and changes of the gut microbiota (4). Lastly, UPF, may alter eating behaviors and eating patterns, promoting snacking and inattentive eating that can interrupt digestive and neural mechanisms that signal satiation and satiety, possibly leading to overconsumption (4).

Estimates of the probability of obesity calculated from individual UPF intake show that the intake of ready-to-eat meals (i.e. French fries, pre-prepared frozen dishes) is associated with obesity in the whole population. This positive gradient may be shaped by how habitual intake of ready-to-eat meals had displaced handmade meals and turned UPF into the main calorie source for many people. An increased share of ready-to-eat meals is a 20th century phenomenon in developed countries (42). The same phenomenon can be seen in developing countries from the 1980s onwards (40). Ready-to-eat meals typically have high energy density and are rich in sugar and fat and poor in fiber (43). These characteristics are risk factors for obesity, and the increased consumption of these products may be one of the explanations for the growing trend in obesity. In the present study, intake of chocolate milk is associated with obesity in the whole population. The chocolate milk referred to milk with added sugar, color additives, flavor, or chocolate and more content of calories compared to regular milk (1). Therefore, this positive association may be shaped by how intake of chocolate milk has replaced regular milk, which could be more safely consumed by children. To encourage the intake of processed foods, children's favorite flavors such as chocolate are added at higher levels than necessary (44). Manufacturers are taking advantage of children's proclivity for sweet-tasting foods and thereby increasing their risks of overconsumption (44). By demonstrating the unique vulnerability of children to the modern food system, the development of evidence-based corrective policies and strategies targeted at this developmental stage is critical.

In this south-Brazilian birth cohort and three Uruguayan cohorts, high intake of UPF was observed. In the studied sample, the mean score of UPF was between 3 and 4, equivalent to the number of subgroups consumed by each child. As previously highlighted in other studies, such eating patterns were associated with a higher intake of added sugar and glycemic load (45). Studies from richer countries, such as Belgium and the US, found that children represent the age group with the highest consumption of UPF (46,47).

In the present study, disparities between dietary patterns related to the intake of UPF were observed. This study shows that in Brazil the consumption of UPF was higher than in Uruguay. There are other striking differences between Brazilian and Uruguayan habitual intake of UPF. Individuals from the Brazilian cohort were the highest consumers of cookies (i.e. biscuits, cake) sweets (i.e. candy, chocolate, jelly, ice cream), or packaged dairy desserts. What these data show is that the habitual intake of UPF is high in the entire population; furthermore, in the Brazilian cohort, only a small fraction of the population does not regularly include these products. A study carried out in 13 urban primary healthcare units in São Paulo, Brazil, demonstrated that UPFs were largely consumed among children under 1 year of age and the intake of UPF was associated with lower maternal education (48). A study of Brazilians aged ten years or over found that

9.0% of the daily energy intake came from processed foods and 21.5% from UPF (49). Similar research by Teixeira de Lacerda et al. describes the participation of 25.2% of UPF in the total energy intake in the diet of children (9). A study from Uruguayan schoolchildren found that 28% of calories came UPF and 18.9% from free sugars, practically equivalent to 100 grams of daily consumption (10). As this study indicates, the highest consumption of UPF by children belonging to the 2015 Birth Cohort of the city of Pelotas could negatively affect children's diets and nutritional status.

The frequency of the consumption of UPF was high in Brazil despite the country having a dietary guideline for Brazilian children under 2 years, which provides information on the degree of food processing and recommends avoiding UPF during early life (50). In Uruguay, there is a dietary guideline for children between 6 months to 2 years, a National Breastfeeding Law, and a guideline for the use of infant formulae, and likely these guidelines contribute to the encouragement and information dissemination to promote healthy food practices and help to reduce the consumption of UPF at this stage of life in the country (51). Another likely explanation of country differences is an observation that in 2013, Uruguay passed a law to protect the health of children who attend educational institutions through the promotion of healthy dietary habits, commonly known as the ‘healthy snacking initiative’ and school assistance is mandatory for 3 years onwards (50). In addition, at least part of the divergence between results in the present study may be due to variation in the instruments for assessing food consumption between studies (FFQ, 24-hour recall and specific questions).

The present study has some limitations that must be outlined. The cross-sectional nature does not allow for establishing causal inference. Other limitations are based on the inherent potential biases when using food questionnaires: underestimating food consumption and differences between the nutritional composition of the consumed foods versus the nutritional composition table used. Measures were taken to minimize these biases in all the cohorts, including having trained interviewers collect the measurements following standard protocols. In addition, the food questionnaires used were specifically built for these studies, including foods that are more consistent with the habits of local people. As the instrument used to record food consumption was not the same in each cohort, some consumption items may have been misclassified. Classification errors are more likely to happen with the frequency of the items. However, for this study we harmonized data to compare each cohort and treated data in a single database. Another potential limitation is that use of the NOVA food classification system enabled to assess underestimated food groups, however, some items may have been misclassified. Finally, the study did not include serving size and no adjustments for energy intake were made, therefore we could not measure amounts of energy and nutrient intake. However, the study by Costa et al. found the Nova score for the consumption of UPF was directly and linearly associated with the percentage of total energy intake from UPF, obtained with a 24-hour dietary recall applied by a trained nutritionist (5).

In conclusion, the present paper shows that higher consumption of UPF is associated with obesity in Uruguayan and Brazilian children younger than 4 years. The present study reinforces the importance of nutrition education actions and more effective public policies for promoting healthier food choices in early childhood.

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TABLE 1. Anthropometric and socioeconomic data for surveyed children and their households

Variable	**Total**	**Uruguay 2013 Cohort 1st wave**	**Uruguay 2013 Cohort 2nd wave**	**Brasil 2015 Cohort 2nd wave**	**Uruguay 2018 Cohort**	
	N (%)	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**p value***
Sex						0.40 [b]
Male	4232(51.17%)	486(51.76%)	866(52.90%)	2164(50.62%)	716(50.46%)	
Female	4040(48.83%)	453(48.24%)	771(47.10%)	2111(49.38%)	705(49.54%)	
Income terciles						<0.001 [b]
1st	2661(33.55%)	344(36.66%)	537(32.86%)	1332(33.66%)	448(31.98%)	
2nd	2694(33.97%)	312(33.23%)	588(35.98%)	1309(32.91%)	485(34.62%)	
3rd	2576(32.48%)	283(33.11%)	509(31.15%)	1316(33.42%)	468(33.40%)	
BMI Z-score						<0.001[b]

Obesity	345(4.61%)	21(2.41%)	85(5.32%)	198(5.43%)	41(2.99%)	
Weight-for-height Z-score						0.001 [b]
Obesity	334(4.59%)	22(2.53%)	70(4.74%)	196(5.40%)	46(3.53%)	
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	
Child age (mo)	43.4(7.31)	34.17(5.94)	45.15(8.46)	45.52(2.58)	41.52(10.01)	<0.001[c]
Exclusive BF duration (mo)	3.38(2.46)	4.37(1.82)	5.06(1.93)	2.12(2.13	5.09(1.95)	<0.001 [c]
z Weight at birth [a]	0.01(1.24)	0.16(1.64)	0.3(1.39)	0.22(1.07)	-1.01(0.6)	<0.001 [c]

BF: indicates breastfeeding; yrs: years; BMI; body mass index; SD: standard deviation

*p value: b. Chi-square test with respect to Cohort; c. ANOVA

a. INTERGROWTH references

TABLE 2. Total ultra-processed food intake, processed meat products, ready to eat/heat food, packaged dairy desserts, sweets, soft drinks, cookies, salty snacks and chocolate milk habitual consumption for surveyed children

Variable	**Total n=8687**	**Uruguay 2013 Cohort 1st wave n=939**	**Uruguay 2013 Cohort 2nd wave n=2052**	**Brasil 2015 Cohort 2nd wave n=4275**	**Uruguay 2018 Cohort n=1421**	
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**p value**
UPF count	3.52(2.53)	2.53(1.54)	1.23(1.45)	5.41(1.97)	2.13(1.45)	<0.001*
	N (%)	**N (%)**	**N (%)**	**N (%)**	**N (%)**	
Processed meat products	3394(42.59%)	270(28.75%)	374(22.86%)	2470(61.64%)	280(20.11%)	<0.001†
Ready to heat and/or eat food	2347(29.47%)	195(20.77%)	72(4.40%)	1815(45.32%)	265(19.04%)	<0.001†
Packaged dairy desserts	5052(63.43%)	477(51.07%)	506(30.93%)	3605(90.01%)	464(33.33%)	<0.001†
Sweets	4434(55.65%)	555(59.10%)	362(22.11%)	3055(76.28%)	462(33.12%)	<0.001 †
Cookies	5012(62.90%)	455(48.82%)	374(22.85%)	3579(89.39%)	604(43.30%)	<0.001 †
Soft drinks	3703(46.44%)	272(29.18%)	686(41.90%)	2016(50.35%)	729(52.29%)	<0.001 †
Chips and salty snacks	2783(34.90%)	- [a]	158(7.7%)	2450(61.19%)	175(12.54%)	<0.001 †
Chocolate milk	2778(34.84%)	152(16.29%)	- [a]	2626(65.58%)	- [a]	<0.001 †

*p value: t-test with respect to Cohort

†p value: Chi-square test with respect to Cohort

UPF: ultra-processed food

a. Note: Data was not asked.

TABLE 3. Prevalence of obesity according to socio-demographic characteristics, exclusive breastfeeding duration and ultra-processed food intake

	Total population (N = 8113)		Uruguay 2013 Cohort 1st wave (N = 871)		Uruguay 2013 Cohort 2nd wave (N = 2301)		Brazil 2015 2nd wave (N = 3601)		Uruguay 2018 Cohort (N = 1340)	
	N(%)	p value *	N(%)	p value *	N(%)	p value *	N(%)	p value *	N(%)	p value *
Sex		0.15		0.80		0.32		0.11		0.31
Male	190(4.97%)		12(2.65%)		50(5.91%)		111(6.05%)		17(2.46%)	
Female	155(4.24%)		9(2.15%)		35(4.66%)		87(4.8%)		24(3.55%)	
Child age (mo) mean (SD)	44.88(6.44)	<0.001†	34.43(6.17)	0,91†	46.68(8.23)	0.10†	45.94(2.48)	0.015†	41.41(9.1)	0.894†
z Weight at birth		<0.001		0.58		<0.001		<0.001		0.23
≤ 1	216(3.74%)		13(2.33%)		39(3.91%)		124(4.36%)		39(2.92%)	
>1	118(8.25%)		7(3.00%)		35(9.43%)		74(9.30%)		2(6.67%)	
Duration EBF (quintiles)		<0.001		0.85		0.23		<0.001		0.59
1	103(7.59%)		1(2%)		8(6.9%)		90(8.47%)		4(3.1%)	
2	51(3.98%)						51(3.98%)			
3	64(3.91%)		7(1.97%)		20(6.54%)		32(4.78%)		5(1.63%)	
4	80(3.38%)		11(2.56%)		33(4.99%)		15(2.9%)		21(2.78%)	
5	7(3.59%)				1(1.22%)		3(8.11%)		3(3.95%)	
Processed meat		0.56		1		0.02		0.88		0.07
Yes	138(4.41%)		6(2.36%)		10(2.74%)		119(5.31%)		3(1.11%)	
No	204(4.73%)		15(2.45%)		75(6.09%)		77(5.49%)		37(3.46%)	
Ready to heat and/or eat food		0.03		0.57		0.65		0.41		0.18
Yes	118(5.43%)		6(3.28%)		5(7.25%)		96(5.75%)		11(4.38%)	
No	223(4.23%)		15(2.2%)		80(5.24%)		100(5.07%)		28(2.58%)	
Packaged dairy desserts		0.20		0.93		0.84		0.43		0.15
Yes	226(4.84%)		10(2.26%)		25(5.05%)		173(5.27%)		18(4.04%)	
No	116(4.17%)		11(2.59%)		60(5.44%)		23(6.41%)		22(2.45%)	
Sweets		0.74		0.17		0.15		0.50		0.38
Yes	184(4.51%)		16(3.11%)		13(3.66%)		145(5.23%)		10(2.28%)	
No	158(4.7%)		5(1.42%)		72(5.8%)		51(5.9%)		30(3.32%)	
Cookies		0.55		0.56		0.02		0.99		0.28
Yes	218(4.72%)		12(2.86%)		10(2.74%)		175(5.37%)		21(3.64%)	
No	124(4.39%)		9(2.02%)		75(6.09%)		21(5.53%)		19(2.48%)	
Soft drinks		0.08		0.80		0.99		0.27		0.15
Yes	174(5.04%)		7(2.82%)		35(5.25%)		106(5.79%)		26(3.69%)	
No	167(4.17%)		14(2.25%)		50(5.38%)		89(4.92%)		14(2.19%)	
Salty snacks		0.46				0.43		0.91		0.23
Yes	130(5.15%)		- [a]		9(7.26%)		119(5.33%)		2(1.2%)	

No	191(4.71%)				76(5.16%)		77(5.47%)		38(3.23%)	
Chocolate milk		0.001		0.99				0.04		
Yes	146(5.73%)		3(2.13%)		- [a]		143(5.94%)		- [a]	
No	71(3.63%)		18(2.48%)				53(4.31%)			
UPF count mean (SD)	3.9(2.5)	0.057†	2.9(1.2)	0.319†	1.3(1.2)	0.087†	5.5(1.8)	0.602†	2.3(1.4)	0.499†

*p value: Chi-square test or Fisher's exact test with respect to surveyed children without obesity

† p value: ANOVA with respect to surveyed children without obesity

SD: standard deviation; UPF: ultra-processed food; EBF: exclusive breastfeeding.

a. Note: Data was not asked

TABLE 4. Likelihood of obesity in relation to ultra-processed food score intake by cohorts and groups of age

	OR(IC95%)[1]	OR(IC95%)[2]	OR(IC95%)[3]	OR(IC95%)[4]	OR(IC95%)[5]
All participants					
UPF count	1.04(1.00-1.09)	1.05(0.99-1.11)	1.00(0.94-1.07)	1.01(0.94-1.08)	1.00(0.94-1.07)
Participants by cohort					
Uruguay 2013 (1st wave)	1.15(0.87-1.51)	1.17(0.88-1.55)	1.14(0.84-1.54)	1.14(0.85-1.52)	1.16(0.87-1.55)
Uruguay 2013 (2nd wave)	0.87(0.74-1.02)	0.90(0.75-1.07)	0.88(0.73-1.07)	0.90(0.74-1.09)	0.87(0.73-1.03)
Brasil 2015	1.02(0.95-1.1)	1.06(0.95-1.18)	1.00(0.92-1.08)	1.00(0.92-1.08)	1.01(0.94-1.09)
Uruguay 2018	1.08(0.87-1.33)	1.08(0.87-1.33)	1.09(0.86-1.39)	1.08(0.86-1.36)	1.09(0.88-1.36)
Participants by group of age					
Children < 48 months	1.10(1.03-1.17)*	1.09(1.02-1.16)*	1.07(0.99-1.15)	1.07(0.98-1.18)	1.10(1.03-1.17)*
Children ≥ 48 months	0.97(0.87-1.07)	0.97(0.87-1.08)	0.92(0.81-1.05)	0.93(0.81-1.07)	1.00(0.90-1.12)

Notes: (1) Bivariate Model; (2) Adjusted for birth weight and age in months (except in age models); (3)Adjusted for sex, age in months, family income, duration of exclusive breastfeeding, cohort (except in cohort models); (4) Adjusted for sex, age in months, duration of exclusive breastfeeding, cohort (except in cohort models); (5) Adjusted for sex, age in months, family income, cohort (except in cohort models)
* Indicates statistical significance with the outcome at the P ≤ 0.05 level.

UPF: ultra-processed food

Figure. Obesity density per ultra-processed food score, by age groups (months)